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EDWARD L. THORNDIKE: THE SELECTIONIST *CONNECTIONIST*

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From the very outset of his work, Thorndike allied himself with the Darwinian proposition that complex phenomena can arise as the cumulative effects of a selection process, here the process envisioned by the law of effect. Thorndike's selectionist approach, when combined with his connectionism, laid the foundation for a synthesis of behavior analysis and neuroscience.

Key words: E. L. Thorndike, selectionism, connectionism, response-outcome associations

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Edward L. Thorndike believed that complex behavior could be understood as an emergent product of the cumulative action of relatively simple processes, notably those summarized by what he came to call the law of effect. "Complex as human life is, it is at bottom explainable by a few principles" (1905, p. 316). More pointedly, "it has been shown that in great measure the intellects and characters of men are explainable by a single law [the law of effect]" (1905, p. 318). Thus, he endorsed a selectionist approach to behavior from his earliest work (cf. Galef, 1998). Thorndike was also a connectionist. That is, he believed that the strengths of connections—what we now call synaptic efficacies—changed as the result of the biological mechanisms that implemented the law of effect. The importance that he ascribed to these mechanisms led him to a neural restatement of the law of effect as the "law of acquired brain connections" (1905, p. 165). With his commitment to selectionism and connectionism, Thorndike allied himself with the resurgent Darwinism of his time and, in so doing, foreshadowed the biobehavioral approach of our time. After documenting Thorndike's selectionist views, I close by noting his prescient comments on a topic of central interest in current associationist accounts of animal learning—the nature of the associations inferred to underlie instrumental learning (i.e., operant conditioning). Thorndike was an associationist as well as a selectionist and connectionist, but his associationism differed from contemporary versions.

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Selectionism

A selection process (see Figure 1) consists of three interrelated steps—variation, selection, and retention (see Dennett, 1995; D. L. Hull, 1973; Mayr, 1988; Sober, 1984). Variation provides the raw material upon which selection operates. It is the source of whatever novelty arises from repeated iterations of the three-step process. Variation is undirected (Campbell, 1974) in the sense that the factors that affect variation are not correlated with those that affect selection. Selection by the environment favors (or disfavors) some variations over others, and confers whatever direction is apparent in the process. Of course, selection is not truly directed because its trajectory is utterly dependent on the environment. When the environment changes, the direction of selection changes. Only the relative constancy of the environment permits the illusion of direction or purpose. Finally, the third step—retention—enables favored variations to endure long enough to contribute to the variation upon which future selection operates. Without retention, the effects of selection could not accumulate and the possibility of complexity would not exist (see Donahoe & Palmer, 1994; Palmer & Donahoe, 1992).

Variation. Thorndike was explicit that whatever creativity or novelty emerged from the process of selection was dependent on the pool of variation upon which the selecting environment acted. "The first necessity of mental progress is fertility in response. Unless the baby does something, it can learn nothing" (1905, p. 209). He recognized that the initial variants upon which selection acted were largely the reflexive relations provided by natural selection (i.e., respondents). "The start-

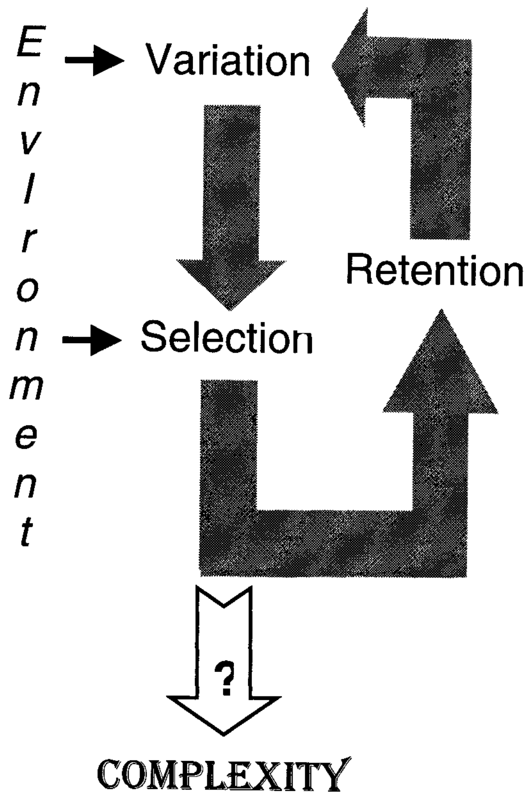

Fig. 1. The three-step process through which the repeated action of relatively simple processes has the potential to produce complex outcomes, as in the emergence of complex behavior through the cumulative effect of reinforcement.

ing point for the formation of any association . . . is the set of instinctive activities'' (1898, p. 13). Thorndike also acknowledged the contribution to variation made by nonelicited behavior: ''Progress was not by seeing through things, but by accidentally hitting upon them'' (1898, p. 106). A fuller appreciation of the role of nonelicited behavior awaited Skinner's (1938) conception of the operant. Thorndike understood that variation was undirected with respect to the selecting factor. ''The one impulse, out of many accidental ones, which leads to pleasure, becomes strengthened'' (1898, p. 45). His designation of the selecting factor as ''pleasure'' or, at other times, as ''satisfaction'' sounds quaint to modern ears, but his conception of undirected variation has a contemporary ring.

Selection. The parallels between selection by ''pleasure'' (i.e., by reinforcement) and natural selection were apparent to Thorndike.

> The development of human mental life may be likened to that of the animal kingdom as a whole. The present animal kingdom is the result of the extinction of those which did not fit the environment. . . . Any man's intellect and character are the results of the existence in his past of many connections, the elimination of those which did not fit their environment so as to bring satisfaction. (1905, p. 317)

Most important, the population of variants on which selection operated was the behavior of an *individual* organism. The focus upon the behavior of the individual was an enduring characteristic of Thorndike's thinking, both his early animal research and his later educational research. It is one of the chief characteristics that differentiates Thorndike and Skinner from their fellows. Even those who otherwise embraced Darwinian thinking, such as Clark Hull (1943), sometimes inadvertently acted as if selection operated on variations in the behavior of *different* organisms. How else to explain the use of group experimental designs that Fisher had correctly devised to measure the effects of natural selection (cf. Sidman, 1960)? An analysis of variation produced by individual differences is appropriate in the study of natural selection but not of selection by reinforcement. Thorndike's focus on the single organism was apparent in the graphs of the behavior of individual animals that he used to communicate his findings (see Chance, 1999) and is explicit in his writings. ''The process is . . . simply the selection of the . . . movement from amongst the many sorts made because of its relatively greater amount of resulting satisfaction'' (1905, p. 204). The foregoing suggests that the focus of selection was a ''movement'' (i.e., behavior). However, other more complete statements indicate that Thorndike considered the unit of selection to be an environment–behavior relation, not behavior alone (cf. Donahoe, Burgos, & Palmer, 1993; Donahoe, Palmer, & Burgos, 1997). To wit, ''The one impulse, out of many accidental ones, which leads to pleasure, becomes strengthened . . . and more firmly associated with the sense-impression of that box's interior'' (1898, p. 45). And, ''any act which in a given situation produces satisfaction becomes associated with that situation, so that when the situation recurs the act is more likely than before to recur also'' (1905, p. 203). Finally, Thorndike was sensitive to the fact that selection produces complexity only by dint of variation. ''Purposive thinking equals spontaneous thinking plus selection'' (1905, p. 264).

Retention. Thorndike also appreciated the essential contribution of retention to the emergence of complexity from a selection process. The behavioral repertoire initially included only ''instinctive activities'' and other ''movements,'' ''but this is the starting point only in the case of the first box experienced'' (1898, p. 14). In subsequent boxes in which his subjects were tested, the behavioral repertoire included the environment–behavior relations that had been selected in prior chambers. The critical role of the accumulation of prior selections was especially apparent in complex human behavior: ''Selection and survival of the fit thoughts . . . are the essentials of purposive thinking'' (1905, p. 265).

Like Darwin before him, Thorndike did not know the biological mechanisms that enabled retention and upon which selection acted. Nevertheless, Thorndike believed that the full development of his approach would require the discovery of these mechanisms.

> How the satisfaction following upon a connection strengthens it . . . must be left [an] unanswered question. Neither psychology nor physiology has yet anything much better than a guess to offer this, the most fundamental question of the mental life of man and the animal kingdom as a whole. All that can be said is that the original satisfiers are as a rule events useful for the survival of the species . . . ; consequently any means by which the[y] . . . could reinforce the connections causing them . . . would, when evolved, be maintained by natural selection. (1905, p. 316)

(Note the use of the term *reinforce* in this statement.) ''Everywhere we have to seek for the physiological basis of mental facts and connections'' (1905, p. 323). The developing modern synthesis of behavior analysis with neuroscience—a biobehavioral approach—would be welcomed by Thorndike as it would by Skinner. ''The experimental analysis of behavior is a rigorous, extensive, and rapidly advancing branch of biology'' (Skinner, 1974, p. 255).

> The physiologist of the future will tell us all that can be known about what is happening inside the behaving organism. His account will be an important advance over a behavioral analysis, because the latter is necessarily ''historical''—that is to say, it is confined to functional relations showing temporal gaps. . . . It will make the picture of human action more nearly complete. (Skinner, 1974, pp. 236–237)

Skinner's earlier reservations about forays into physiology stemmed from pragmatic considerations—the absence of the requisite neuroscience—not from principled objections to such a synthesis. Behavior analysts such as Jack Michael recognize that the present situation is quite different: ''I would strongly urge anyone starting a research career in behavior analysis in the late 1900s to include extensive training in the neurosciences. And I would also urge extensive training in computer science sufficient to understand computer modeling'' (Michael, 1998, p. 160).

The Nature of the Selected ''Association''

Consistent with Michael's admonitions, Thorndike's ''most fundamental question'' is currently being pursued by integrating the experimental analysis of behavior and neuroscience using neural networks (e.g., Donahoe & Palmer, 1989, 1994). The interconnected ensemble of units that constitutes a neural network may be regarded as a much-mutated descendant of Thorndike's connectionism. It is ironic that simulation via neural networks has recently been brought to bear on a matter of contention between Thorndike's early views of the law of effect and current statements of associationism, that other branch of the Thorndikian tree. The issue is the nature of the association inferred to underlie operant—or instrumental—conditioning. Present-day associationism generally takes the position that an instrumental response occurs because ''the reinforcer is encoded as a consequence of the response'' (Rescorla & Colwill, 1989, p. 291) or, stated in other terms, ''instrumental learning leads to the development of response-outcome associations'' (Colwill, 1994, p. 31; see also Colwill & Rescorla, 1990). Concerning this view, Thorndike asked: ''Do they [animals] ever conclude from inference that a certain act will produce a certain desired result, and so do it? . . . Although it is in a way superfluous to give the *coup de grace* to the despised theory that animals reason, I think it is worthwhile to settle this question once for all'' (1898, p. 39). ''The commonly accepted view . . . is that the sight of the inside of the box reminds the animal of his *previous pleasant experience after escape and of the movements* which he made which were immediately followed by and so associated with that escape'' [i.e., a response–outcome association] (1898, p. 65). Thorndike disagreed: ''This view has stood unchallenged, but its implication is false. It implies that an animal, whenever it thinks of an act, can supply an *impulse to do* the act'' (1898, p. 66). ''The groundwork of animal associations is not the association of *ideas,* but the association of . . . sense-impression with *impulse*'' (1898, p. 71). In short, Thorndike rejected the notion that is implicit in the concept of response–outcome association—that of a response initiated by an autonomous organism. Consideration of the discriminative effects of conditioned respondents provides an interpretation that is more congenial to Thorndike's views. The behavior that fostered inferences about response–outcome associations can be interpreted as the joint control of operants and respondents by the environment, with feedback from the respondent modulating the strength of the operant (Donahoe & Palmer, pp. 108–109; cf. Trapold & Overmeir, 1972). The law of effect, when implemented by the neural mechanisms sought in the law of acquired brain connections, supports Thorndike's views (and Skinner's as well; see Palmer, 1998) that selection by reinforcement changes the environmental guidance of behavior, a conclusion that is not well characterized as the formation of response–outcome associations.

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